

Listing of Claims

1. (Currently amended) A magnetic resonance method to determine changes in microvascular blood volume without the use of exogenous contrast or endogenous paramagnetic contrast using the parenchymal tissue signal, the method including:

performing a ~~blood-nulling~~ blood signal-reduction magnetic resonance excitation sequence ~~(70)~~ that substantially ~~nulls~~ reduces a magnetic resonance signal from blood while substantially retaining parenchymal tissue signal; and

subsequent to the performing of the ~~blood-nulling~~ blood signal-reduction magnetic resonance excitation sequence ~~(70)~~, performing a readout magnetic resonance sequence ~~(72)~~ to acquire a magnetic resonance signal arising predominantly from parenchymal tissue other than the nulled blood; and

determining a microvascular blood volume parameter based on the acquired magnetic resonance signal arising predominantly from parenchymal tissue.

2. (Currently amended) The magnetic resonance method as set forth in claim 1, wherein the performing of a ~~blood-nulling~~ blood signal-reduction magnetic resonance sequence ~~(70)~~ includes:

performing an inversion recovery magnetic resonance excitation sequence ~~(70)~~ having an inversion time ~~(60)~~ to substantially ~~null~~ reduce the magnetic resonance signal from blood.

3. (Currently amended) The magnetic resonance method as set forth in claim 2, wherein the performing of an inversion recovery magnetic resonance sequence ~~(70)~~ includes:

applying an inversion radio frequency pulse ~~(74)~~;

delaying for the inversion time ~~(60)~~; and

applying an excitation radio frequency pulse ~~(80)~~.

4. (Currently amended) The magnetic resonance method as set forth in claim 3, wherein:

the applying of the inversion radio frequency pulse ~~(74)~~ is performed without an accompanying spatially selective magnetic gradient pulse; and

the applying of the excitation radio frequency pulse ~~(80)~~ is performed with an accompanying spatially selective magnetic field gradient pulse ~~(82)~~.

5. (Currently amended) The magnetic resonance method as set forth in claim 3, wherein the performing of an inversion recovery magnetic resonance sequence ~~(70)~~ further includes:

applying additional inversion radio frequency pulses to maintain the blood signal in a substantially ~~nulled~~ reduced condition.

6-11. (Canceled)

12. (Currently amended) The magnetic resonance method as set forth in ~~claim 2~~ claim 1, further including:

generating a reconstructed image from the acquired magnetic resonance signal.

13. (Currently amended) The magnetic resonance method as set forth in claim 12, further including:

subsequent to performing the readout magnetic resonance sequence, inducing a physiological perturbation;

subsequent to inducing the physiological perturbation, repeating performing the ~~inversion recovery~~ blood signal-reduction magnetic resonance excitation sequence ~~(70)~~ and performing the readout magnetic resonance sequence ~~(72)~~ to acquire a second magnetic resonance signal arising predominantly from parenchymal tissue ~~other than the nulled blood~~; and

generating a perturbation reconstructed image from the acquired second magnetic resonance signal.

14. (Currently amended) The magnetic resonance method as set forth in claim 12, further including:

subsequent to performing the readout magnetic resonance sequence (72), inducing a physiological perturbation;

subsequent to inducing the physiological perturbation, repeating performing the ~~inversion-recovery~~ blood signal-reduction magnetic resonance excitation sequence (70);

subsequent to repeating the performing of the ~~inversion-recovery~~ blood signal-reduction magnetic resonance excitation sequence (70), performing a plurality of readout magnetic resonance sequences (72) each having a different echo time to acquire a plurality of magnetic resonance signals corresponding to the plurality of echo times;

generating a plurality of perturbation reconstructed images from the acquired plurality of magnetic resonance signals corresponding to the plurality of echo times; ~~and, the~~ determining of the microvascular blood volume parameter being based on a temporal evolution of a physiological response to the physiological perturbation based on the plurality of perturbation reconstructed images.

15. (Currently amended) The magnetic resonance method as set forth in claim 14, wherein the determining of ~~a temporal evolution~~ the microvascular blood volume parameter includes:

computing a change in vascular space occupancy signal between perturbation reconstructed images and corresponding unperturbed reconstructed images for each echo time to produce change in vascular space occupancy signal versus echo time data (106); and

fitting the change in vascular space occupancy signal versus echo time data (106) to a mathematical model to obtain a blood volume parameter value (118).

16. (Currently amended) The magnetic resonance method as set forth in claim 12, further including:

~~determining a T1 value of tissue (132, 134);~~

computing a tissue magnetization (~~M~~) based on the T1 value of the tissue (~~132~~, ~~134~~);
generating a normalized reconstructed image (~~142~~) by dividing the reconstructed image by the tissue magnetization; and
estimating a blood volume parameter value (~~146~~) based on the normalized reconstructed image (~~142~~).

17. (Canceled)

18. (Currently amended) The magnetic resonance method as set forth in claim 12, wherein performing the readout magnetic resonance sequence (~~72~~) effects imaging of a subject brain region of a subject brain, and the method further includes:

providing a reference image (~~152~~) of a reference brain region; and
comparing the reconstructed image with the reference image (~~152~~) to detect an abnormality of the subject brain region.

19. (Currently amended) The magnetic resonance method as set forth in claim 18, wherein providing the reference image (~~152~~) of a reference brain region includes repeating:

performing the ~~inversion-recovery~~ blood signal-reduction magnetic resonance excitation sequence (~~70~~),
performing the readout magnetic resonance sequence (~~72~~), and
generating the reconstructed image on the reference brain region to generate the reference image (~~152~~).

20. (Original) The magnetic resonance method as set forth in claim 19, wherein the reference brain region is selected from a group consisting of:

a brain region of a contralateral side of the subject brain corresponding to the subject brain region,
a brain region of a brain other than the subject brain which corresponds to the subject brain region, and

a brain region of the subject brain other than the subject brain region.

21. (Canceled)

22. (Currently amended) The magnetic resonance method as set forth in claim 2, wherein performing the readout magnetic resonance sequence ~~(72)~~ to acquire a magnetic resonance signal arising predominantly from parenchymal tissue includes performing one or more of:

- a single-shot imaging sequence,
- a single-shot echo planar sequence,
- a multi-shot imaging sequence,
- a spectroscopy sequence,
- a multiple slice image,
- a one-dimensional, two-dimensional, or three dimensional spatial encoding sequence,
- a fractional k-space acquisition sequence,
- a spin echo readout sequence, and
- a gradient echo readout sequence.

23. (Currently amended) A magnetic resonance system configured to determine changes in microvascular blood volume without the use of exogenous contrast or endogenous paramagnetic contrast using the parenchymal tissue signal, the system including:

a blood ~~nulling~~ signal reduction means ~~(10, 12, 16, 18, 30, 32, 34)~~ for performing a blood ~~nulling~~ signal reduction magnetic resonance excitation sequence ~~(70)~~ that substantially ~~nulls~~ reduces a magnetic resonance signal from blood while retaining an effective parenchymal tissue signal; and

a readout means ~~(10, 12, 16, 18, 30, 32, 36)~~ for performing a readout magnetic resonance sequence ~~(72)~~ to acquire a magnetic resonance signal arising predominantly from parenchymal tissue ~~other than the nulled blood~~, the readout means ~~(10, 12, 16, 18,~~

~~30, 32, 36~~) operating subsequent to operation of the blood nulling signal reduction means ~~(10, 12, 16, 18, 30, 32, 34)~~;

a reconstruction means for generating a reconstructed image from the acquired magnetic resonance signal; and

a means for computing a blood volume parameter value from the reconstructed image.

24. (Currently amended) The magnetic resonance system as set forth in claim 23, wherein the blood nulling signal reduction means ~~(10, 12, 16, 18, 30, 32, 34)~~ includes:

an inversion recovery means ~~(10, 12, 16, 18, 30, 32, 34)~~ for performing an inversion recovery magnetic resonance excitation sequence ~~(70)~~ having an inversion time ~~(60)~~ in which magnetic resonance of blood is substantially nulled effective to produce a substantially reduced blood signal.

25-28. (Canceled)

29. (Currently amended) The magnetic resonance system as set forth in ~~claim 28~~ claim 23, wherein the means ~~(130)~~ for computing a blood volume parameter value ~~(118, 146)~~ includes:

a means ~~(136, 140)~~ for normalizing the reconstructed image based on a T1 value of tissue ~~(132, 134)~~ to generate a tissue-normalized reconstructed image; and

a means ~~(144)~~ for computing the blood volume from the tissue-normalized reconstructed image.

30. (Currently amended) The magnetic resonance system as set forth in ~~claim 28~~ claim 23, wherein the means ~~(100)~~ for computing a blood volume parameter value ~~(118, 146)~~ includes:

a means ~~(104)~~ for computing an intermediate parameter ~~(106)~~ functionally related to blood volume for a plurality of reconstructed images produced by repetitively

invoking the readout means and the reconstruction means with a corresponding plurality of echo times ~~(102)~~; and

a means ~~(110)~~ for fitting a parameterized model to the intermediate parameters ~~(106)~~ and the corresponding echo times ~~(102)~~, the parameterized model having parameters including a rest blood volume ~~(118)~~ and a blood volume change ~~(124)~~.

31. (Currently amended) The magnetic resonance system as set forth in ~~claim 27~~ claim 23, further including:

a means ~~(154)~~ for combining the reconstructed image with a reference image ~~(152)~~ to identify an abnormality in the reconstructed image.

32. (New) A magnetic resonance method for assessing microvascular blood volume, the method comprising:

acquiring a parenchymal tissue magnetic resonance signal from parenchymal tissue under different parenchymal blood volume perturbing conditions that change the vascular space occupancy within the parenchymal tissue; and

determining a parenchymal vascular space occupancy-related parameter based on the acquired parenchymal tissue magnetic resonance signals.

33. (New) The magnetic resonance method as set forth in claim **32**, wherein the acquiring comprises:

(i) performing a blood signal-reduction magnetic resonance excitation sequence that substantially reduces a magnetic resonance signal from blood relative to a magnetic resonance signal from parenchymal tissue; and

(ii) acquiring the parenchymal tissue magnetic resonance signal with the magnetic resonance signal from blood substantially reduced relative to the magnetic resonance signal from parenchymal tissue by the performing operation (i).

34. (New) The magnetic resonance method as set forth in claim **32**, wherein the determining comprises:

computing change in vascular space occupancy caused by the different parenchymal blood volume perturbing conditions.